BESIII physics and future tau-charm factories

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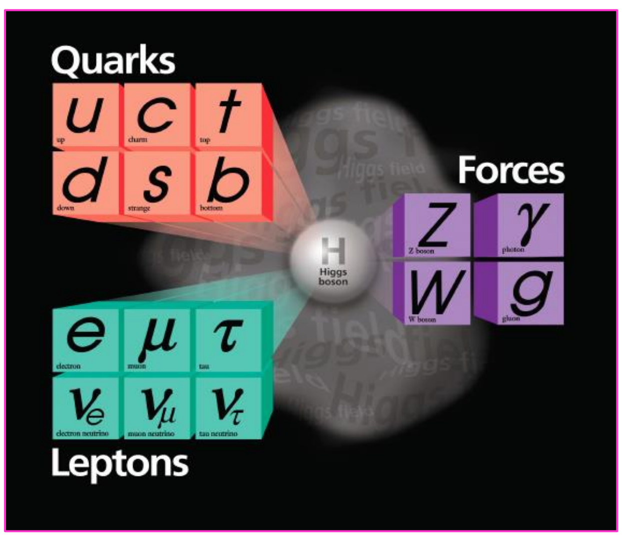
The Standard Model

The standard model of particle physics is a well-tested theoretical framework,

However, the SM has a number of issues need further investigation:

- The nature of quark confinement
- Matter-antimatter asymmetry of the Universe
- Gravity, dark matter, neutrino masses, numbers of flavors, etc.



19 free parameters of the SM

Masses

Parameter	Value	Method
m_u	1.9 MeV	Lattice
m_d	4.4 MeV	Lattice
m_s	87 MeV	Lattice
m_c	1.3 MeV	Collider
m_b	4.24 MeV	Collider
m_t	173 GeV	Collider
m_e	511 keV	Non-collider
m_μ	106 MeV	Non-collider
m_τ	1.78 GeV	Collider
m_Z	91.2 GeV	Collider
m_H	125 GeV	Collider

Couplings

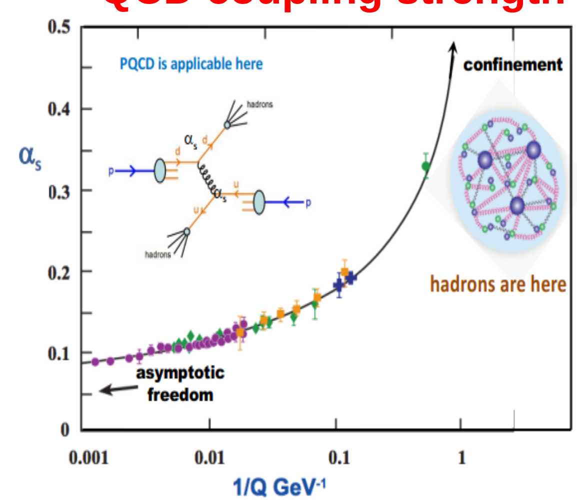
Parameter	Value	Method
α	0.0073	non-collider + collider
G_F	1.17×10^{-5}	Non-collider
α_s	0.12	Lattice + collider

Flavour and CP violation

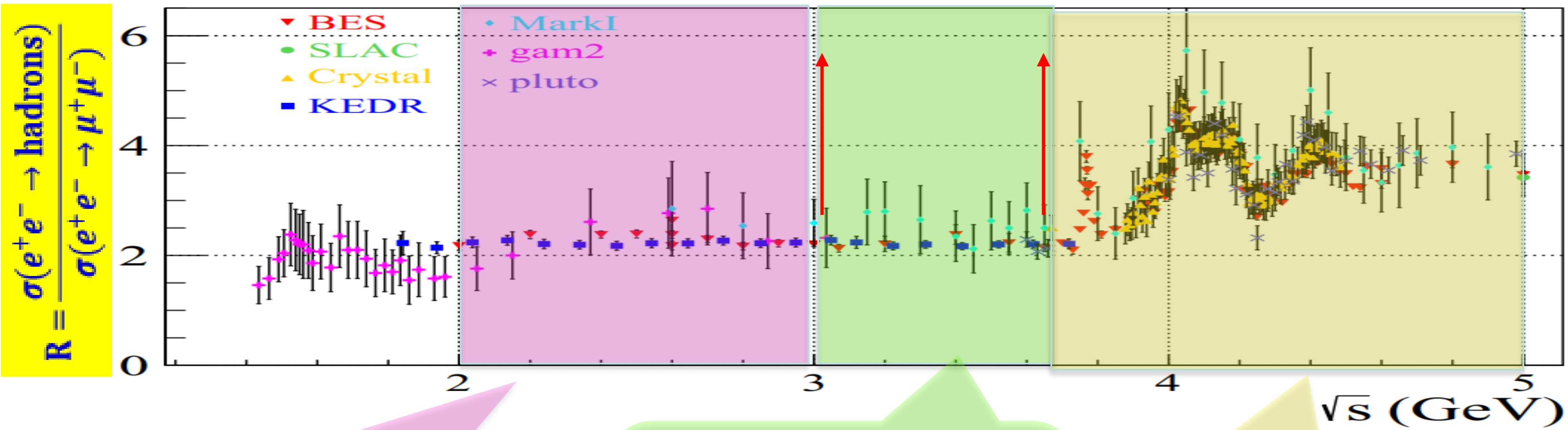
Parameter	Value	Method
θ_{12} (CKM)	13.1°	Collider
θ_{23} (CKM)	2.4°	Collider
θ_{13} (CKM)	0.2°	Collider
δ (CKM-CPV)	0.995	Collider
θ (strong CP)	~0	Non-collider

Does not include neutrino masses and mixing angles

QCD coupling strength



Physics in tau-Charm Region



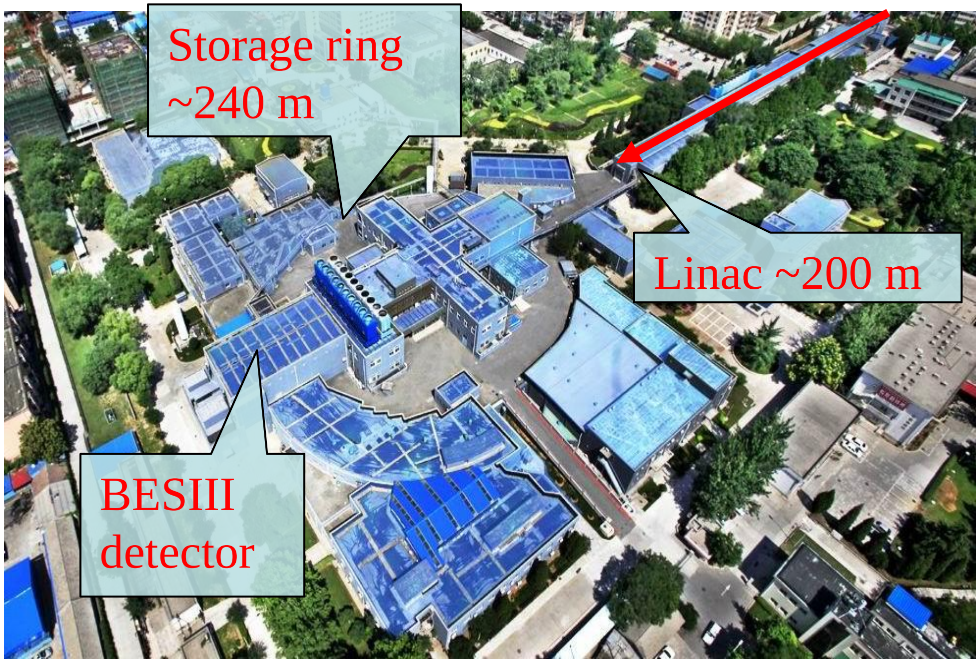
- Hadron form factors
- Y(2175) resonance
- Mutltiquark states with s quark,
- MLLA/LPHD and QCD sum rule predictions

- Light hadron spectroscopy
- Gluonic and exotic states
- Process of LFV and CPV
- Rare and forbidden decays
- Physics with τ lepton

- XYZ particles
- Physics with D mesons
- fD and fDs
- D0-D0 mixing
- Charm baryons

- ☐ The interplay of perturbative and nonperturbative dynamics
- ☐ Unique features: Rich of resonances, Threshold characteristics, Quantum correlation

BEPCII: a τ-charm factory



E_{cm}= 2.0-4.6 GeV (2.0-4.9 GeV since 2019)

Energy spread: $\Delta E \approx 5 \times 10^{-4}$

Peak luminosity in continuously operation

@E_{cm}= 3.77 GeV: ~0.8× 10^{33} $cm^{-2}s^{-1}$

Electromagnetic Calorimeter

CsI(Tl): L=28 cm

Barrel σ_E=2.5%

Endcap σ_E=5.0%

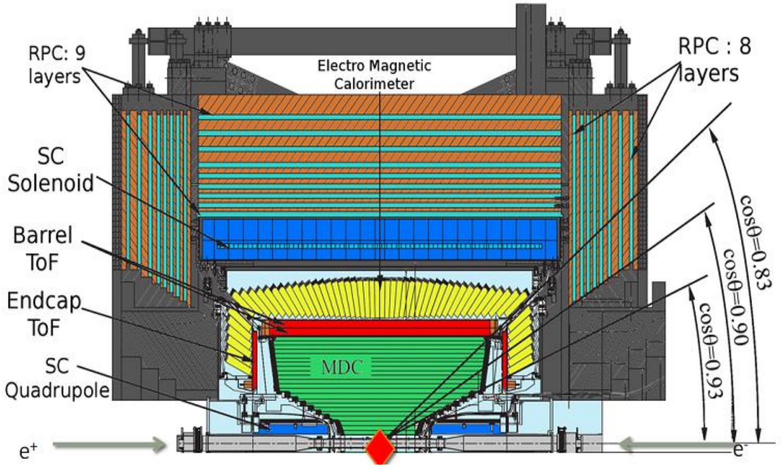
Muon Counter

RPC

Barrel: 9 layers

Endcap: 8 layers

$\sigma_{spatial}$: 1.48 cm



Main Drift Chamber

Small cell, 43 layer

σ_{xy}=130 μm

dE/dx~6%

σ_p/p= 0.5% at 1 GeV

Time Of Flight

Plastic scintillator

σ_T(barrel): 80 ps

σ_T(endcap): 110 ps

(update to 65 ps with MRPC)

BESIII Collaboration

15 countries, 74 institutions

~500 members

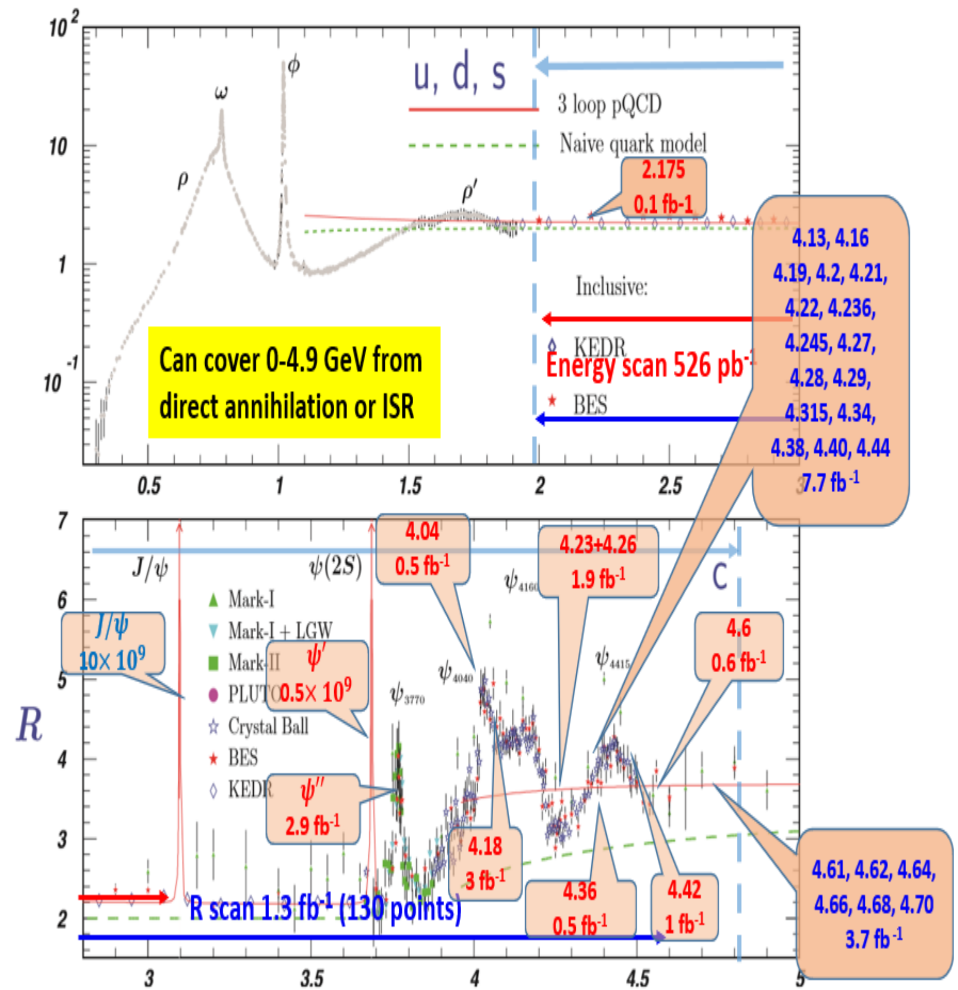
Data samples collected at BESIII

Data sets collected so far include,

- **10×10^{9} J/ψ events**
- 0.5×10^{9} ψ' events
- Scan data [2.0, 3.08] GeV; [3.735, 4.600] GeV, 130 energy points, about 2.0 fb^{-1}
- Large data sets for XYZ study above 4.0 GeV about 17 fb^{-1}

Unique data sets at open charm thresholds

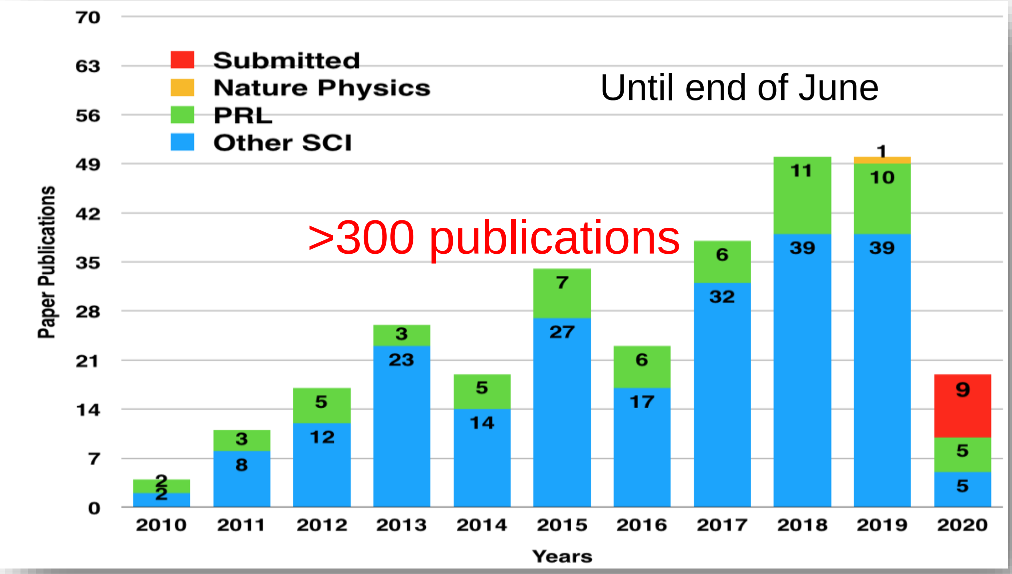
$\sqrt{s}$ / GeV	$\mathcal{L}$ / fb^{-1}	
3.77	2.93	$D\bar{D}$
4.008	0.48	DD^*, $\psi(4040)$, $D_s^+D_s^-$
4.18	3.2	$D_sD_s^*$
4.6-4.7	4.3	$\Lambda_c^+\bar{\Lambda}_c^-$



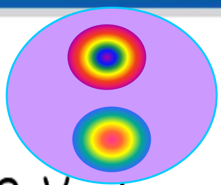
BESIII physics highlights

- ✓ Best precision of tau mass measurement ($\Delta m_\tau = 0.18$ MeV)
- ✓ Charmonium and XYZ spectroscopy: $Z_c(3900)$, X(3872), Y(4260)…
- ✓ Light hadron & searches of exotics: X(1835), glueball…
- ✓ Precision charm physics: CKM, decay constant, form factors, LFU, Λ_c decays
- ✓ Probe EM structure of baryons: G_E, G_M of proton, neutron, hyperons
- ✓ Hyperon-anti-hyperon pairs from J/ψ and ψ' decays:

  asymmetry parameters, CP violation, polarizations
- ✓ …



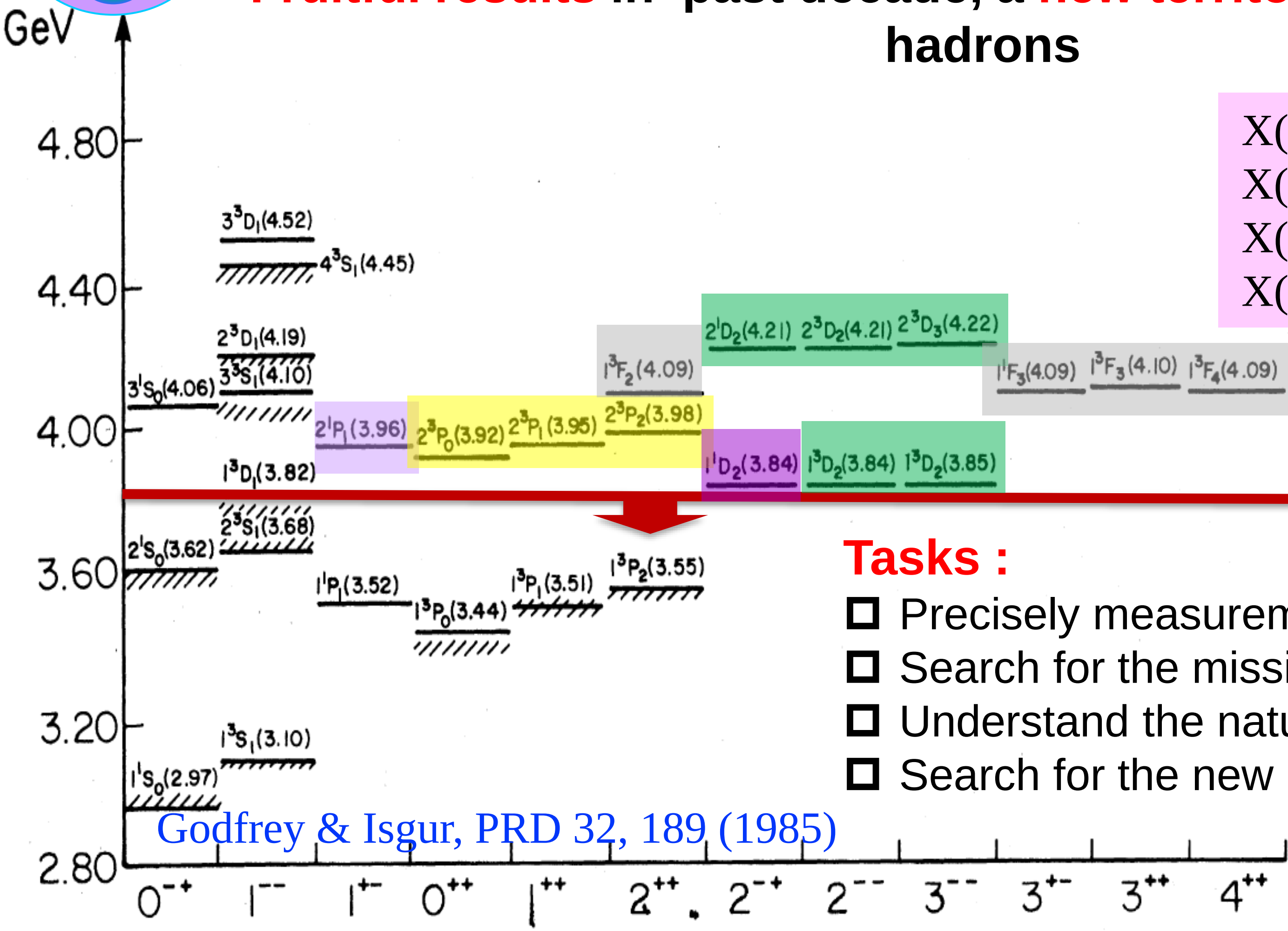
Charmonium (Like) spectroscopy



Excellent platform to explore the QCD

Fruitful results in past decade, a new territory to study exotic hadrons

X	Y	Z
X(3872)	Y(3940)	Z(3900)
X(3940)	Y(4008)	Z(4020)
X(4160)	Y(4260)	Z(4050)
X(4350)	Y(4360)	Z(4200)
	Y(4660)	Z(4250)
		Z(4430)



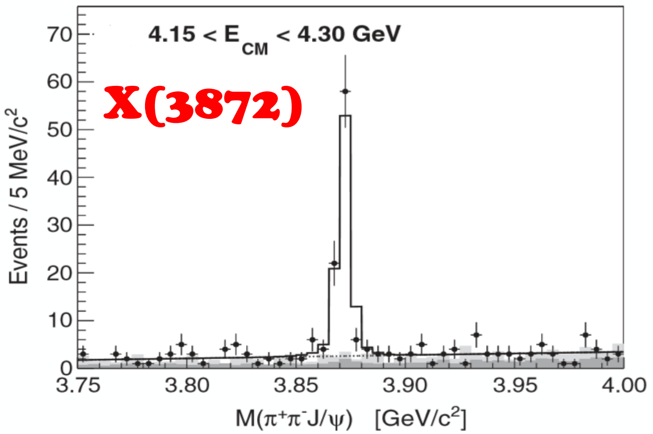
Godfrey & Isgur, PRD 32, 189 (1985)

Tasks :

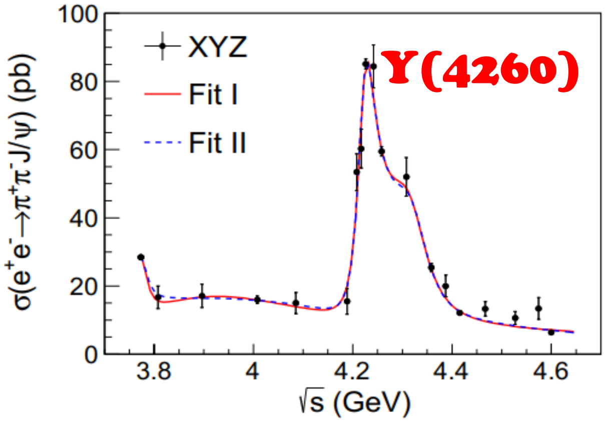
- Precisely measurement the transition
- Search for the missing states
- Understand the nature of unknown states
- Search for the new exotic states

The XYZ states

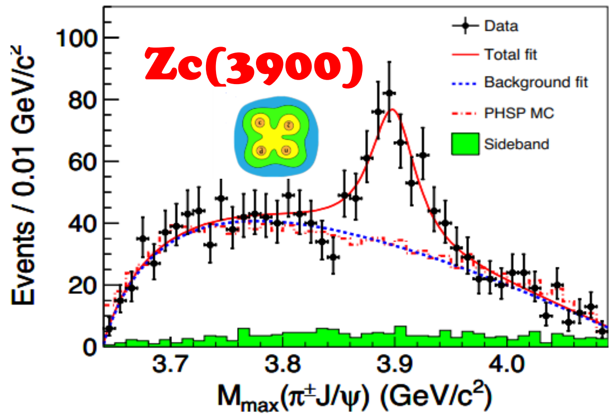
PRL 122, 202001 (2019)



PRL 118, 092001 (2017)

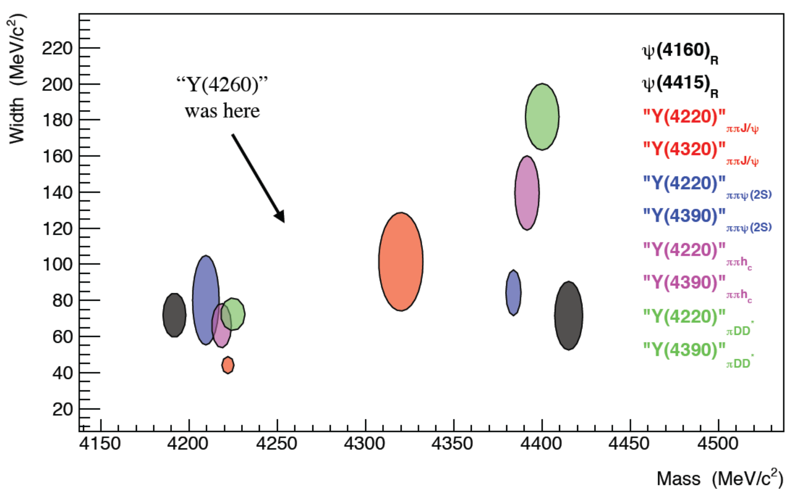


PRL 110, 252001 (2013)



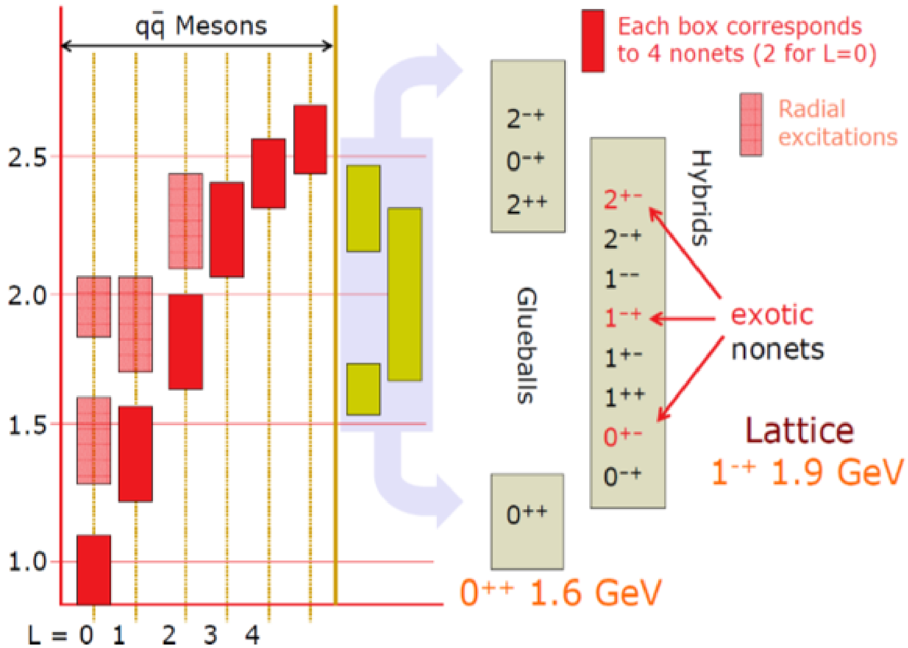
- XYZ states are studied extensively at BESIII with **high efficiency** & **low background**
- **Relations** between **XYZ** states are building
- **Various models** are proposed to understand their structure(tetraquark, molecule, hybrid…)
- **More efforts** are needed to understand their **properties**

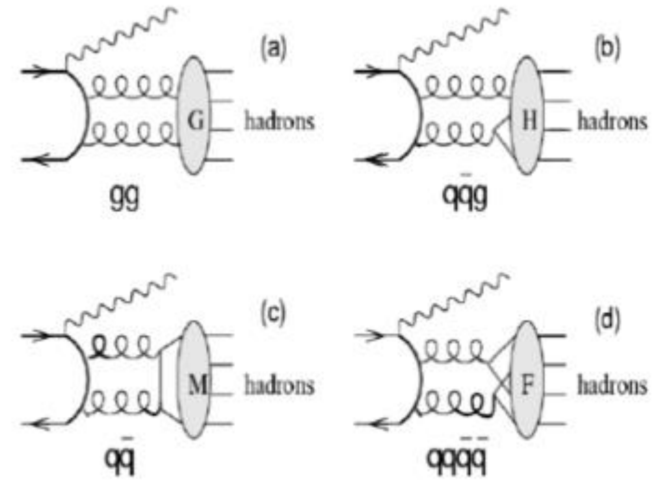
Parameters of the Peaks in e$^+$e$^-$ Cross Sections



More details can be found in Ryan's talk in RF7

Systematic study of glueball at BESIII





$$\Gamma(J/\psi \to \gamma G) \sim O(\alpha\alpha_s^2), \Gamma(J/\psi \to \gamma H) \sim O(\alpha\alpha_s^3),$$

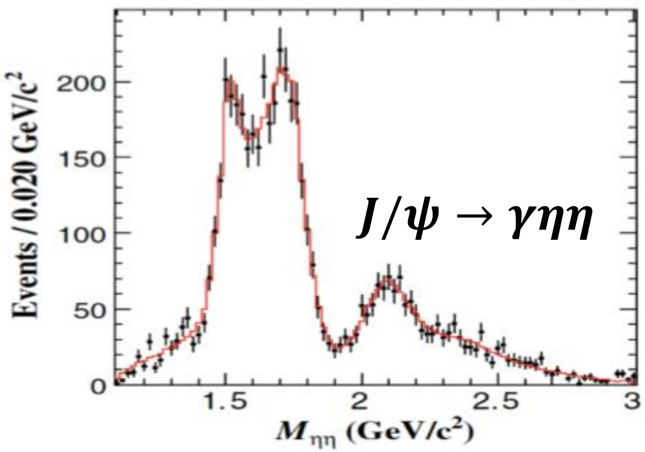
$$\Gamma(J/\psi \to \gamma M) \sim O(\alpha\alpha_s^4), \Gamma(J/\psi \to \gamma F) \sim O(\alpha\alpha_s^4)$$

Charmonium decays provides an ideal hunting ground for light glueballs

- ➢ **“Glue-rich” process**
- ➢ **Clean high statistics data samples from e^+e^- production**

PWA of $J/\psi \to \gamma\eta\eta / \gamma K_S^0 K_S^0$

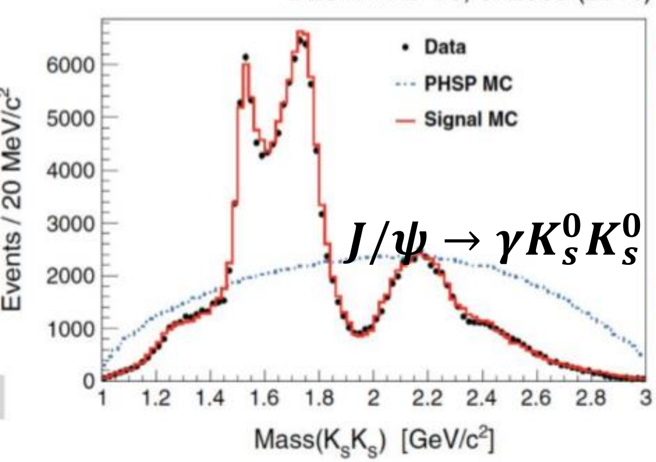
BESIII PRD 87, 092009 (2013)



Resonance	Mass (MeV/c^2)	Width (MeV/c^2)	$\mathcal{B}(J/\psi \to \gamma X \to \gamma\eta\eta)$	Significance
$f_0(1500)$	1468^{+14+23}_{-15-74}	$136^{+41+28}_{-26-100}$	$(1.65^{+0.26+0.51}_{-0.31-1.40}) \times 10^{-5}$	8.2σ
$f_0(1710)$	$1759 \pm 6^{+14}_{-25}$	$172 \pm 10^{+32}_{-16}$	$(2.35^{+0.13+1.24}_{-0.11-0.74}) \times 10^{-4}$	25.0σ
$f_0(2100)$	$2081 \pm 13^{+24}_{-36}$	273^{+27+70}_{-24-23}	$(1.13^{[illegible]}_{-0.10-0.28}) \times 10^{-4}$	13.9σ
$f_2'(1525)$	$1513 \pm 5^{+4}_{-10}$	75^{+12+16}_{-10-8}	$(3.42^{+0.43+1.37}_{-0.51-1.30}) \times 10^{-5}$	11.0σ
$f_2(1810)$	1822^{+29+66}_{-24-57}	$229^{+52+88}_{-42-155}$	$(5.40^{+0.60+3.42}_{-0.67-2.35}) \times 10^{-5}$	6.4σ
$f_2(2340)$	$2362^{+31+140}_{-30-63}$	$334^{+62+165}_{-54-100}$	$(5.60^{+0.62+2.37}_{-0.65-2.07}) \times 10^{-5}$	7.6σ

Br of $f_0(1710)$ ~10x larger than $f_0(1500)$

BESIII PRD 98, 072003 (2018)



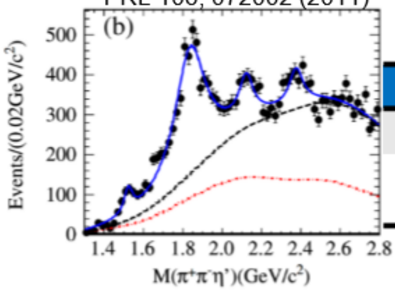
Resonance	M (MeV/c^2)	$M_{\rm PDG}$ (MeV/c^2)	Γ (MeV/c^2)	$\Gamma_{\rm PDG}$ (MeV/c^2)	Branching fraction	Significance
$K^*(892)$	896	895.81 ± 0.19	48	47.4 ± 0.6	$(6.28^{+0.16+0.59}_{-0.17-0.52}) \times 10^{-6}$	35σ
$K_1(1270)$	1272	1272 ± 7	90	90 ± 20	$(8.54^{+1.07+2.35}_{-1.20-2.13}) \times 10^{-7}$	16σ
$f_0(1370)$	$1350 \pm 9^{+12}_{-2}$	1200 to 1500	$231 \pm 21^{+28}_{-48}$	200 to 500	$(1.07^{+0.08+0.36}_{-0.07-0.34}) \times 10^{-5}$	25σ
$f_0(1500)$	1505	1504 ± 6	109	109 ± 7	$(1.59^{+0.16+0.18}_{-0.16-0.56}) \times 10^{-5}$	23σ
$f_0(1710)$	$1765 \pm 2^{+1}_{-1}$	1723^{+6}_{-5}	$146 \pm 3^{+7}_{-1}$	139 ± 8	$(2.00^{+0.03+0.31}_{-0.02-0.10}) \times 10^{-4}$	$\gg 35\sigma$
$f_0(1790)$	$1870 \pm 7^{+2}_{-3}$	...	$146 \pm 14^{+7}_{-15}$	...	$(1.11^{[illegible]}_{-0.06-0.32}) \times 10^{-5}$	24σ
$f_0(2200)$	$2184 \pm 5^{+4}_{-2}$	2189 ± 13	$364 \pm 9^{+4}_{-7}$	238 ± 50	$(2.72^{+0.08+0.17}_{-0.06-0.47}) \times 10^{-4}$	$\gg 35\sigma$
$f_0(2330)$	$2411 \pm 10 \pm 7$	...	$349 \pm 18^{+23}_{-1}$	...	$(4.95^{+0.21+0.66}_{-0.21-0.72}) \times 10^{-5}$	35σ
$f_2(1270)$	1275	1275.5 ± 0.8	185	$186.7^{+2.2}_{-2.5}$	$(2.58^{+0.08+0.59}_{-0.09-0.20}) \times 10^{-5}$	33σ
$f_2'(1525)$	1516 ± 1	1525 ± 5	$75 \pm 1 \pm 1$	73^{+6}_{-5}	$(7.99^{+0.03+0.69}_{-0.04-0.50}) \times 10^{-5}$	$\gg 35\sigma$
$f_2(2340)$	$2233 \pm 34^{+9}_{-25}$	2345^{+50}_{-40}	$507 \pm 37^{+18}_{-21}$	322^{+70}_{-60}	$(5.54^{+0.34+3.82}_{-0.40-1.49}) \times 10^{-5}$	26σ
0^{++} PHSP	...	...	...	...	$(1.85^{+0.05+0.68}_{-0.05-0.26}) \times 10^{-5}$	26σ
2^{++} PHSP	...	...	...	...	$(5.73^{+0.99+4.18}_{-1.00-3.74}) \times 10^{-5}$	13σ

BESIII's results favor $f_0(1710)$ as scalar glueball, more experimental measurements are needed.

Anomalous line shape of η′π+π- near $p\bar{p}$ mass threshold

X(1835) observed in J/ψ→γη′π⁺π⁻

PRL 106, 072002 (2011)



225 Million J/psi

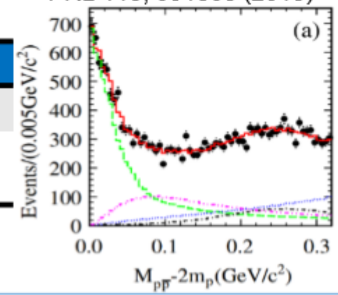
X(1835) $J^{PC}=0^{-+}$
M = $1844 \pm 9^{+16}_{-25}$ MeV/c^2
Γ = 192^{+20+62}_{-17-43} MeV/c^2

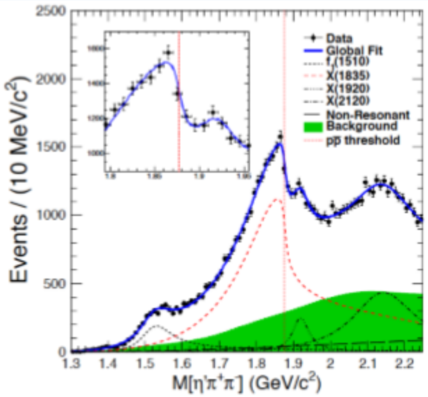
X($p\bar{p}$) $J^{PC}=0^{-+}$
M = $1832^{+19}_{-5}{}^{+18}_{-17} \pm 19$ MeV/c^2
Γ = 13 ± 19 MeV/c^2 (< 76 MeV/c^2 @ 90% C.L.)

X($p\bar{p}$) observed in J/ψ→γ$p\bar{p}$

PRL 108, 112003 (2012)

PRL 115, 091803 (2015)





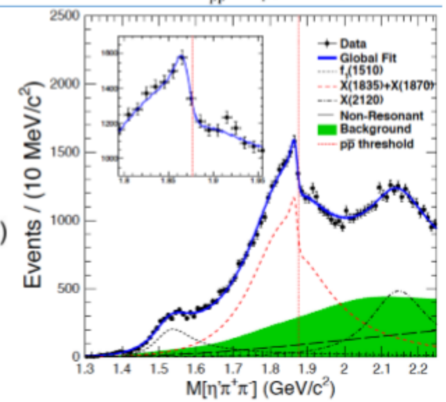
Connection is emerging

PRL 117, 042002 (2016)

1.3 Billion J/psi

Model 1:
Flatte lineshape with strong coupling to $p\bar{p}$ and one additional, narrow Breit-Wigner at ~1920 MeV/c²

Model 2:
Coherent sum of X(1835) Breit-Wigner and one additional, narrow Breit-Wigner at ~1870 MeV/c²



The anomalous line shape can be modeled two models with equally good fit quality

- **Suggest the existence of a state, either a broad state with strong couplings to $p\bar{p}$, or a narrow state just below the $p\bar{p}$ mass threshold**
- **Support the existence of a $p\bar{p}$ molecule-like state or bound state**

Charm physics

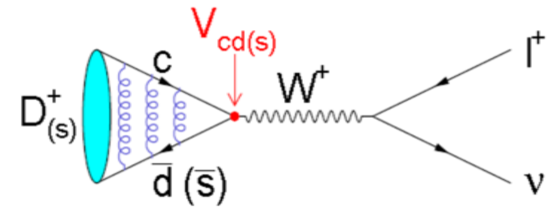
CKM matrix elements are fundamental SM parameters that describe the mixing of quark fields due to weak interaction.

$$\begin{pmatrix} d' \\ s' \\ b' \end{pmatrix} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ \boxed{V_{cd} \; V_{cs}} & & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} \begin{pmatrix} d \\ s \\ b \end{pmatrix}$$

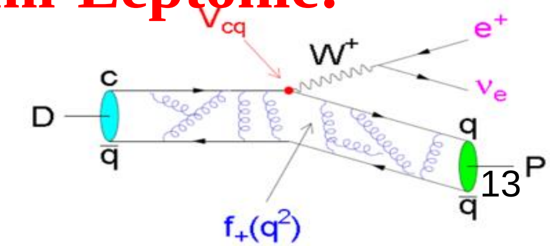
Leptonic and semileptonic decays of charmed hadrons (D^0, D^+, D_s^+, Λ_c^+) provide ideal testbeds to explore weak and strong interactions

1. $|V_{cs(d)}|$: better test on CKM matrix unitarity
2. (Semi-)leptonic $D_{(s)}$ decays allow for LFU tests
3. $f_{D(s)+}, f_+^{K(\pi)}(0)$: test of LQCD

Purely Leptonic:



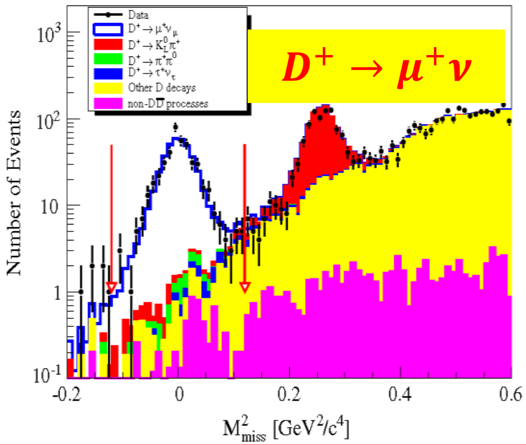
Semi-Leptonic:



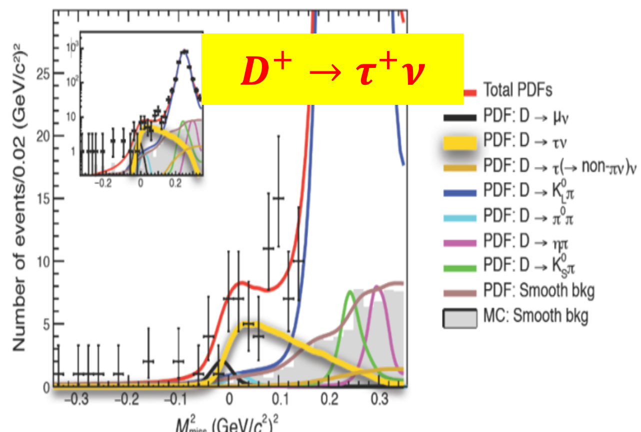
$D_{(s)}$ (Semi-)Leptonic decay

2.93 fb^{-1} data @3.773 GeV

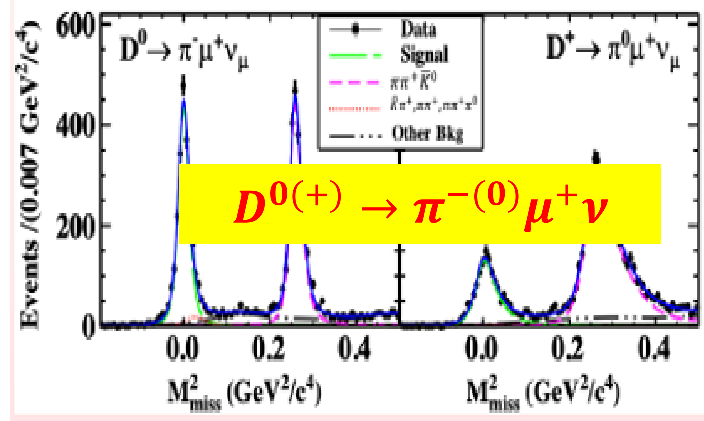
PRD 89, 051104 (2014)



PRL 123, 211802 (2019)

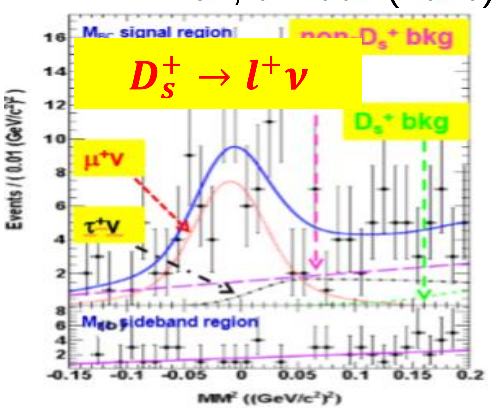


PRL 121, 171803 (2019)



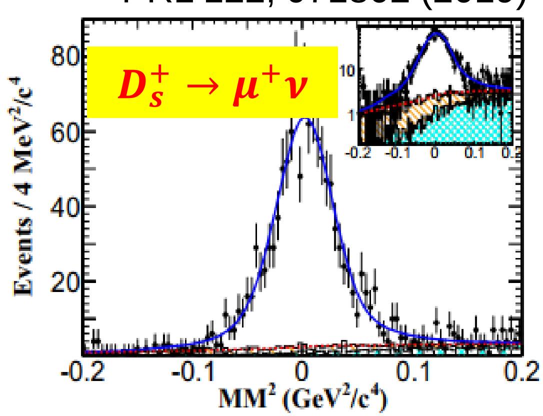
0.48 fb^{-1} data @4.01 GeV

PRD 94, 072004 (2016)

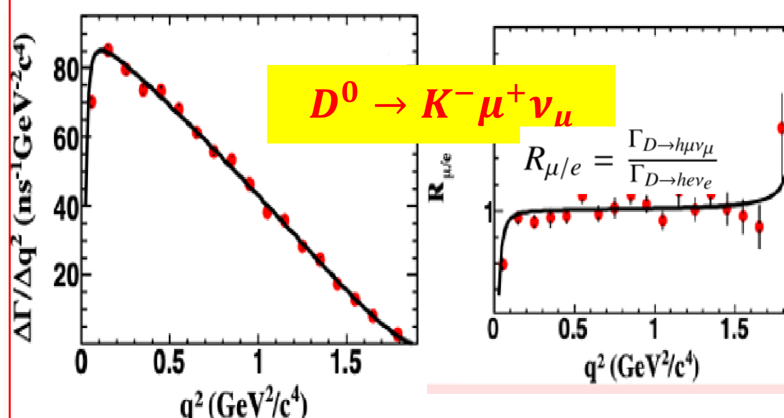


3.19 fb^{-1} data @4.178 GeV

PRL 122, 071802 (2019)

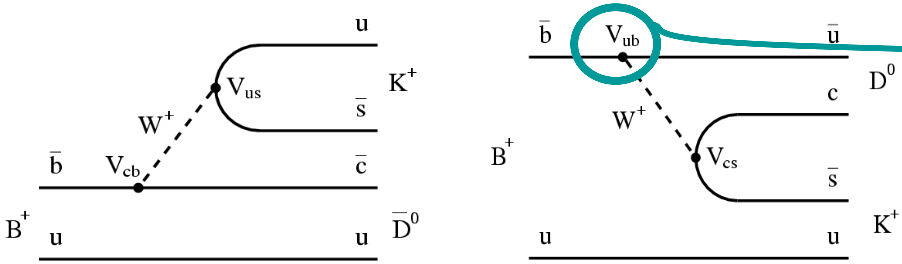


PRL 122, 011804 (2019)



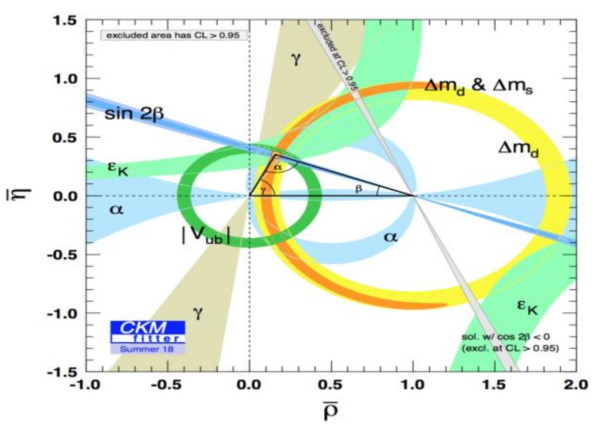
Determination of γ/ϕ_3 angle

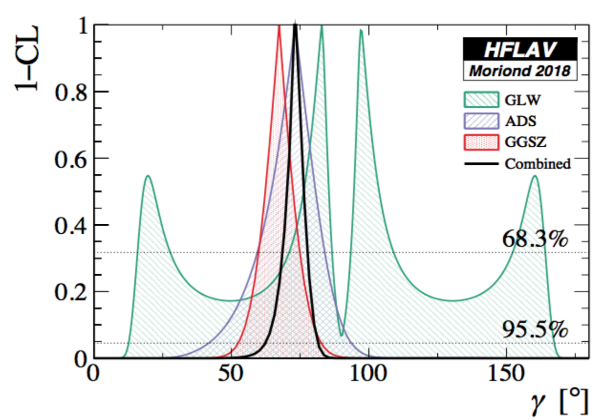
- The cleanest way to extract γ is from B→DK decays:



$$\frac{A(B^+ \to D^0 K^+)}{A(B^+ \to \overline{D^0} K^+)} \equiv r_B e^{i(\delta_3 + \phi_3)}$$

  - Interference between tree-level decays; theoretically clean
  - current uncertainty $\sigma(\gamma) \sim 5^0$
  - however, theoretical relative error $\sim 10^{-7}$ (very small!)
- Information of *D decay strong phase* is needed
  - Best way is to employ quantum coherence of DD production at threshold





More details can be found in Xiaorui's talk in RF1

Precision measurements of Λ_c decay

PDG2014

$\Gamma(p\overline{K}^0\pi^0)/\Gamma(pK^-\pi^+)$ — Γ_7/Γ_2

VALUE	EVTS	DOCUMENT ID		TECN	COMMENT
0.66±0.05±0.07	774	ALAM	98	CLE2	$e^+e^- \approx \Upsilon(4S)$

$\Gamma(p\overline{K}^0\eta)/\Gamma(pK^-\pi^+)$ — Γ_8/Γ_2

Unseen decay modes of the η are included.

VALUE	EVTS	DOCUMENT ID		TECN	COMMENT
0.25±0.04±0.04	57	AMMAR	95	CLE2	$e^+e^- \approx \Upsilon(4S)$

$\Gamma(p\overline{K}^0\pi^+\pi^-)/\Gamma(pK^-\pi^+)$ — Γ_9/Γ_2

VALUE	EVTS	DOCUMENT ID		TECN	COMMENT
0.51±0.06 OUR AVERAGE					
0.52±0.04±0.05	985	ALAM	98	CLE2	$e^+e^- \approx \Upsilon(4S)$
0.43±0.12±0.04	83	AVERY	91	CLEO	e^+e^- 10.5 GeV
0.98±0.36±0.08	12	BARLAG	90D	NA32	π^- 230 GeV

$\Gamma(pK^-\pi^+\pi^0)/\Gamma(pK^-\pi^+)$ — Γ_{10}/Γ_2

VALUE	EVTS	DOCUMENT ID		TECN	COMMENT
0.67±0.04±0.11	2606	ALAM	98	CLE2	$e^+e^- \approx \Upsilon(4S)$

$\Gamma(pK^*(892)^-\pi^+)/\Gamma(p\overline{K}^0\pi^+\pi^-)$ — Γ_{11}/Γ_9

Unseen decay modes of the $K^*(892)^-$ are included.

VALUE	EVTS	DOCUMENT ID		TECN	COMMENT
0.44±0.14	17	ALEEV	94	BIS2	nN 20–70 GeV

$\Gamma(p(K^-\pi^+)_{\text{nonresonant}}\pi^0)/\Gamma(pK^-\pi^+)$ — Γ_{12}/Γ_2

VALUE	EVTS	DOCUMENT ID		TECN	COMMENT
0.73±0.12±0.05	67	BOZEK	93	NA32	π^- Cu 230 GeV

PDG2019

$\Gamma(pK^0_S\pi^0)/\Gamma_{\text{total}}$ — Γ_7/Γ

VALUE (%)	EVTS	DOCUMENT ID		TECN	COMMENT
1.96±0.13 OUR FIT	Error includes scale factor of 1.1.				
1.87±0.13±0.05	558	ABLIKIM	16	BES3	$e^+e^- \to \Lambda_c\overline{\Lambda}_c$, 4.599 GeV

$\Gamma(pK^0_S\pi^0)/\Gamma(pK^-\pi^+)$ — Γ_7/Γ_2

Measurements given as a $\overline{K}^0$ ratio have been divided by 2 to convert to a K^0_S ratio.

VALUE	EVTS	DOCUMENT ID		TECN	COMMENT
0.314±0.018 OUR FIT					
0.33 ±0.03 ±0.04	774	ALAM	98	CLE2	$e^+e^- \approx \Upsilon(4S)$

$\Gamma(nK^0_S\pi^+)/\Gamma_{\text{total}}$ — Γ_8/Γ

VALUE (%)	EVTS	DOCUMENT ID		TECN	COMMENT
1.82±0.23±0.11	83	ABLIKIM	17H	BES3	e^+e^- at 4.6 GeV

$\Gamma(p\overline{K}^0\eta)/\Gamma(pK^-\pi^+)$ — Γ_9/Γ_2

Unseen decay modes of the η are included.

VALUE	EVTS	DOCUMENT ID		TECN	COMMENT
0.25±0.04±0.04	57	AMMAR	95	CLE2	$e^+e^- \approx \Upsilon(4S)$

$\Gamma(pK^0_S\pi^+\pi^-)/\Gamma_{\text{total}}$ — Γ_{10}/Γ

VALUE (%)	EVTS	DOCUMENT ID		TECN	COMMENT
1.59±0.12 OUR FIT	Error includes scale factor of 1.2.				
1.53±0.11±0.09	485	ABLIKIM	16	BES3	$e^+e^- \to \Lambda_c\overline{\Lambda}_c$, 4.599 GeV

$\Gamma(pK^0_S\pi^+\pi^-)/\Gamma(pK^-\pi^+)$ — Γ_{10}/Γ_2

Measurements given as a $\overline{K}^0$ ratio have been divided by 2 to convert to a K^0_S ratio.

VALUE	EVTS	DOCUMENT ID		TECN	COMMENT
0.255±0.015 OUR FIT	Error includes scale factor of 1.1.				
0.257±0.031 OUR AVERAGE					
0.26 ±0.02 ±0.03	985	ALAM	98	CLE2	$e^+e^- \approx \Upsilon(4S)$
0.22 ±0.06 ±0.02	83	AVERY	91	CLEO	e^+e^- 10.5 GeV
0.49 ±0.18 ±0.04	12	BARLAG	90D	NA32	π^- 230 GeV

$\Gamma(pK^-\pi^+\pi^0)/\Gamma_{\text{total}}$ — Γ_{11}/Γ

VALUE (%)	EVTS	DOCUMENT ID		TECN	COMMENT
4.42±0.31 OUR FIT	Error includes scale factor of 1.5.				
4.53±0.23±0.30	1849	ABLIKIM	16	BES3	$e^+e^- \to \Lambda_c\overline{\Lambda}_c$, 4.599 GeV

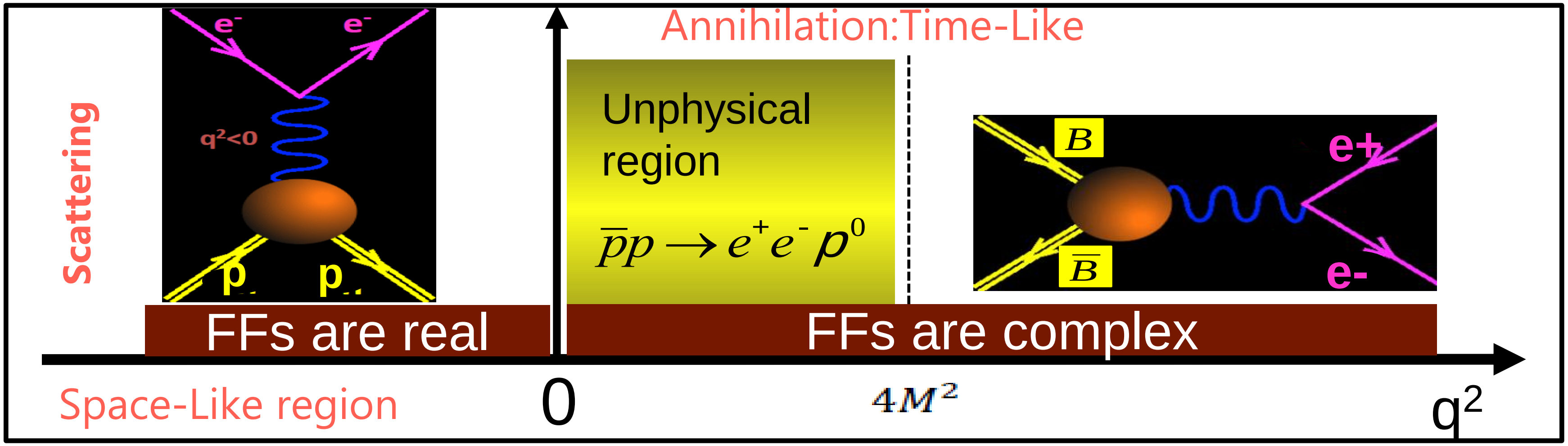
$\Gamma(pK^-\pi^+\pi^0)/\Gamma(pK^-\pi^+)$ — Γ_{11}/Γ_2

VALUE	EVTS	DOCUMENT ID		TECN	COMMENT

With the unique data near $\Lambda_c^+\overline{\Lambda}_c^-$ threshold (567 pb^{-1} @ 4.6 GeV), lots of improved measurements have been achieved for Λ_c decays at BESIII

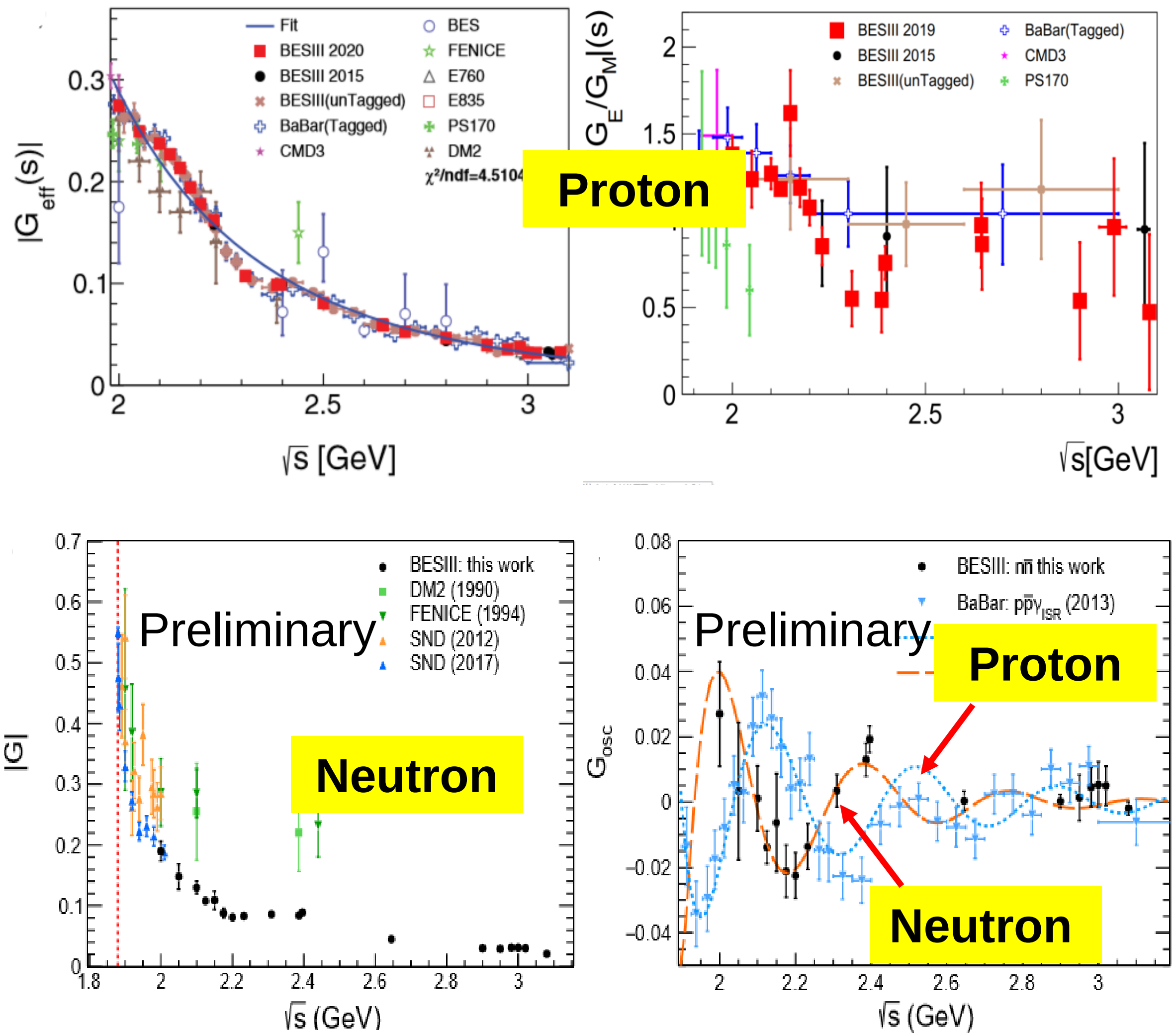
Nucleon electromagnetic form factors

- **Fundamental properties of the nucleon**
  - ➢ **Connected to charge, magnetization distribution**
  - ➢ **Crucial testing ground for models of the nucleon internal structure**
- **Can be measured from space-like processes (eN) (precision 1%) or time-like process (precision 10%-30% before BESIII)**



Nucleon electromagnetic form factors

688 pb^{-1} data @2.0-3.08 GeV PRL 124, 042001 (2020)



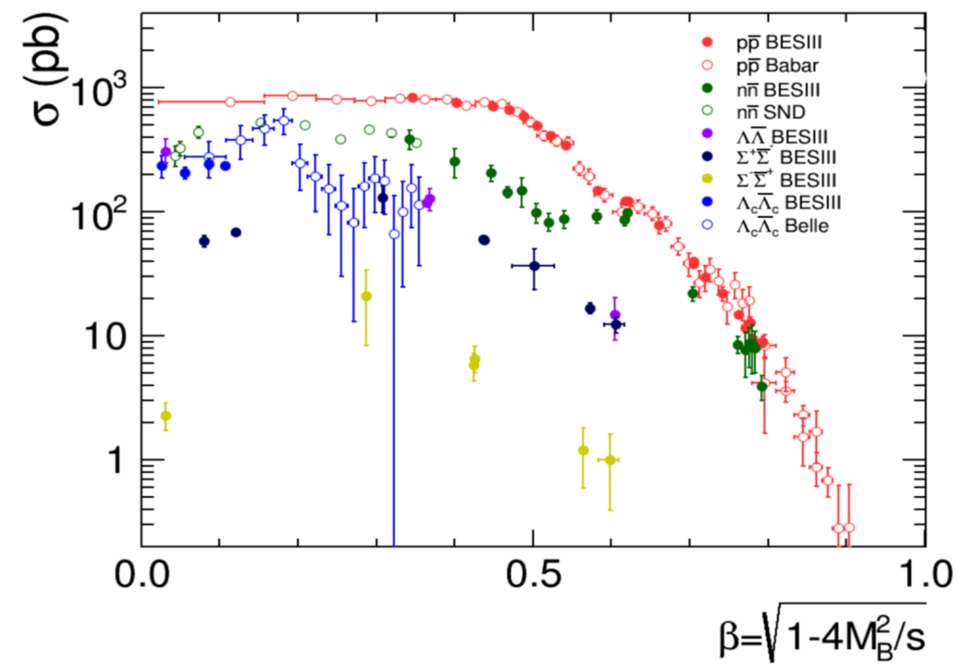
- ✓ **Both ISR and scan approach are used to obtain proton EMFFs**
- ✓ **Scan approach is applied on neutron EMFFs**
- ✓ **Significantly improved precision of nucleon EMFFs in timelike (comparable to spacelike)**
- ✓ **Observed oscillation of neutron with a relative phase shift around 90° to proton**

Threshold effects of baryons

- The **Born cross section** for $e^+e^- \to \gamma^* \to B\bar{B}$, can be expressed in terms of electromagnetic form factor G_E and G_M :

$$\sigma_{B\bar{B}}(q) = \frac{4\pi\alpha^2 C\beta}{3q^2}\left[|G_M(q)|^2 + \frac{1}{2\tau}|G_E(q)|^2\right]$$

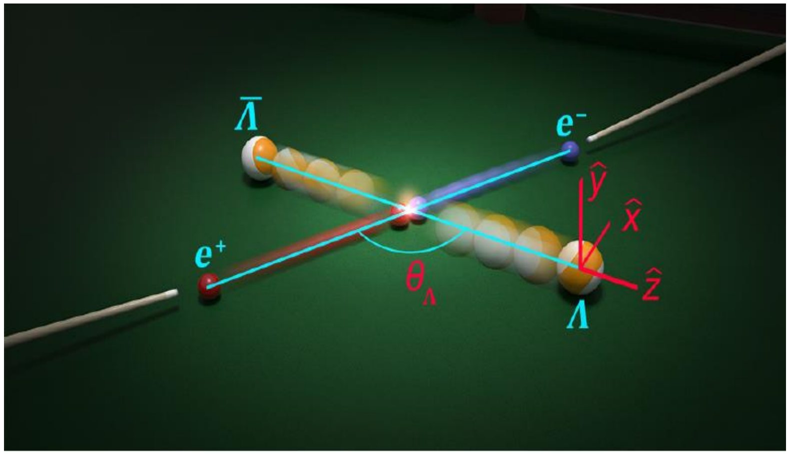
- The **Coulomb factor** $C=\frac{\pi\alpha}{\beta}\frac{1}{1-exp\left(-\frac{\pi\alpha}{\beta}\right)}$ for a charged $B\bar{B}$ pair, and equals to 1 for a neutral $B\bar{B}$ pair



$$\sigma_{B\bar{B}}(4m_B^2) = \frac{\pi^2\alpha^3}{3m_B^2}|G|^2 = 848|G|^2\left(\frac{m_p}{m_B}\right)^2 \text{ pb}$$

Non-zero cross sections at threshold are observed in various baryon pair production: $p\bar{p},\ n\bar{n},\ \Lambda\bar{\Lambda},\ \Lambda_c^+\bar{\Lambda}_c^-\ \ldots$

Polarization of Λ hyperons and CPV



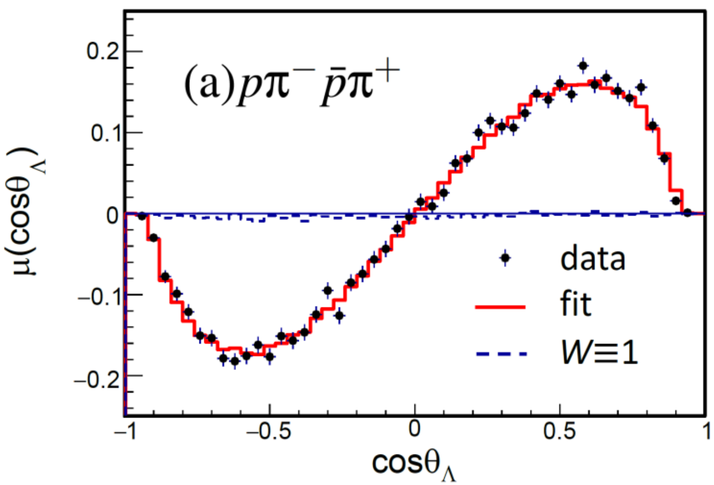
Nature Phys. 15, 631-634 (2019)

BESIII results with 1.3 billion J/ψ

~7σ upward shift from all previous measurements

Parameters	This work	Previous results
α_ψ	$0.461 \pm 0.006 \pm 0.007$	0.469 ± 0.027 [14]
$\Delta\Phi$	$(42.4 \pm 0.6 \pm 0.5)^\circ$	–
α_-	$0.750 \pm 0.009 \pm 0.004$	0.642 ± 0.013 [16]
α_+	$-0.758 \pm 0.010 \pm 0.007$	-0.71 ± 0.08 [16]
$\bar{\alpha}_0$	$-0.692 \pm 0.016 \pm 0.006$	–
A_{CP}	$-0.006 \pm 0.012 \pm 0.007$	0.006 ± 0.021 [16]
$\bar{\alpha}_0/\alpha_+$	$0.913 \pm 0.028 \pm 0.012$	–

2% level sensitivity for CPV test
SM prediction: 10^{-4}~10^{-5}



Highest sensitivity test of CPV in baryon sector! More results with 10 billion J/ψ and other hyperons are coming.

More details can be found in Andrzej's talk in RF1

Physics programs for future data taking at BESIII

BESIII white paper: Chin. Phys. C 44, 040001 (2020)

Wishlist comprises about 40 fb^{-1}:

- 10~17 fb^{-1} on $\psi(3770)$
- 6 fb^{-1} at 4.18 GeV →Ds meson
- Scan at the highest energy?
- Continue XYZ scan
- Large Z_c samples: 5 fb^{-1} each at 4.23, 4.42 GeV
- High-statistics data samples around 2.2, 2.4 GeV
- 3 billion ψ'
- …

Upgrades of detector:

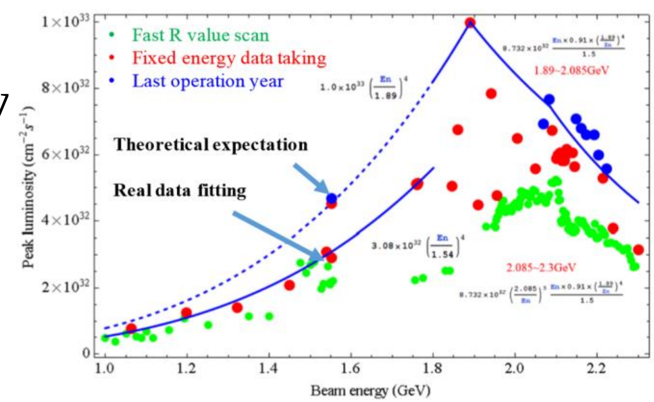
✓ Endcap TOF upgrade (2015)

➢ Inner most part of the drift chamber

➢ Super Conduct magnet

Gain luminosity with "Topup" injection

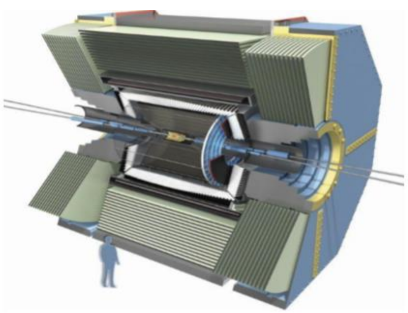
A factor of 2 gain for lattice optimized at J/ψ running



BESIII detector is in good status, inner detector upgrade in progress, will continue data taking for another 5-10 years

Future tau charm factory

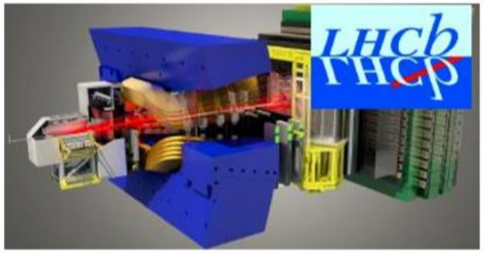
- Limited by length of storage ring, BEPCII has no space and potential for major upgrade
- Physics study limited by the statistics, collision energy
- There is strong competition/synergy between $c-\tau$ and B factories



- BelleII

Started in 2019

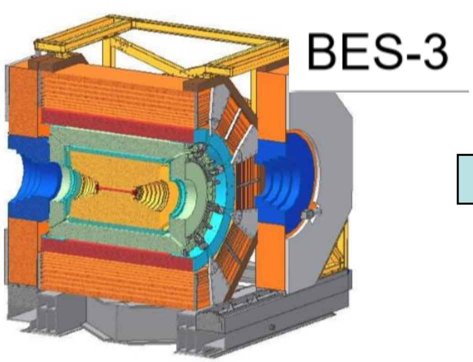
50 ab^{-1} in total



- LHCb

Upgrade now

50/300 fb^{-1} (Run 3/4)



Future tau charm factory proposed in China and Russia

Super tau-Charm Facility in China

- Peaking luminosity >0.5×10^{35} cm^{-2}s^{-1} at 4 GeV
- Potential to increase luminosity and realize beam polarization
- Energy range E_{cm} = 2-7 GeV
- A nature extension and a viable option for China accelerator project in the post BEPCII/BESIII era

Parameters	Phase1	Phase2
Circumference/m	600~800	600~800
Optimized Beam Energy/GeV	2.0	2.0
Beam Energy Range/GeV	1-3.5	1-3.5
Current/A	1.5	2.0
Emittance $(\varepsilon_x/\varepsilon_y)$/nm·rad	6/0.06	5/0.05
β Function @IP (β_x^*/β_y^*)/mm	60/0.6	50/0.5(estimated)
Full Collision Angle 2θ/mrad	60	60
Tune Shift ξy	0.06	0.08
Hourglass Factor	0.8	0.8
Aperture and Lifetime	15σ, 1000s	15σ, 1000s
Luminosity @Optimized Energy/×10^{35}cm^{-2}s^{-1}	~0.5	~1.0

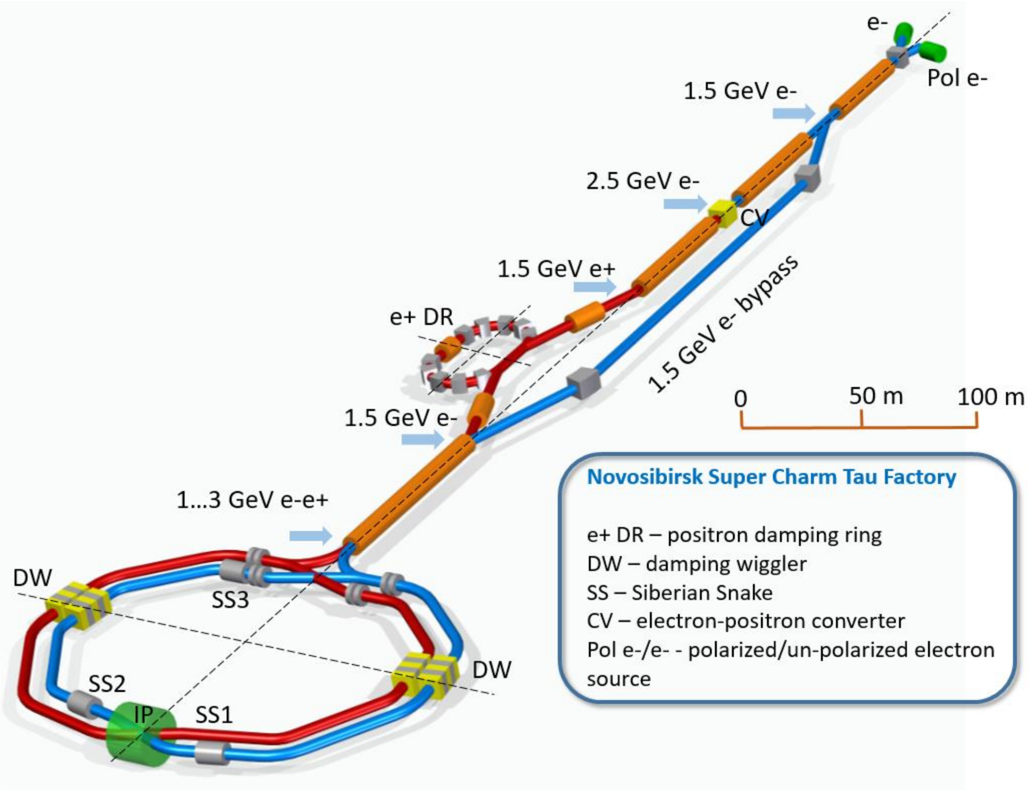
Expected data with 1ab^{-1}

CME	No. of Events
3.097	3 T J/ψ
3.686	500 B ψ’
3.77	3.6 B D^0 2.8 B D^+
4.04	0.2 B Ds
4.23	1 B Y(4260) 100 M Zc 5 M X(3872) 3.6 M tau
4.63	0.5 M Λ_c
>5	fine scan

More details can be found in Haiping’s talk in RF7

Super Charm-Tau Factory in Russia

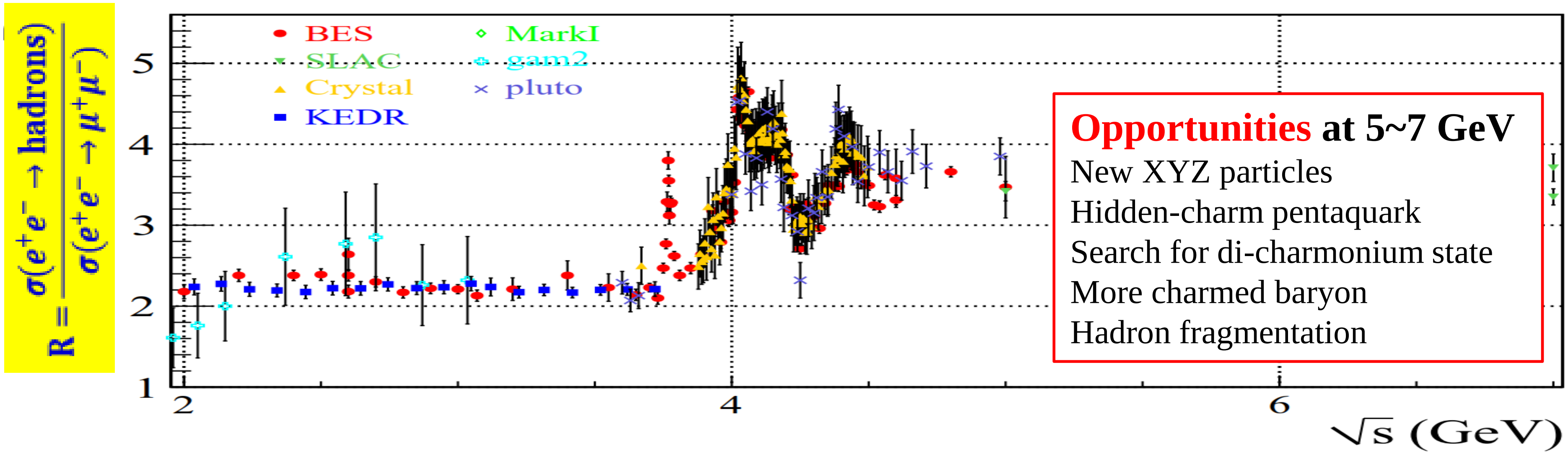
- **Symmetric e$^+$e$^-$ collider, energy region E$_{cm}$=2-6 GeV**
- **Luminosity 10^{35} cm^{-2}s^{-1} @ 4GeV**
- **Crab waist beam collision, longitudinal e$^-$ polarization**



Circumference	478.092 m			
2θ	60 mrad			
β_x^*/β_y^*	50 mm / 0.5 mm			
F_{RF}	349.9 MHz			
E_{beam} (GeV)	**1**	**1.5**	**2**	**3**
I (A)	1	2.2	2.2	2
N_{bunch}	500	490	420	290
ε_x (nm)	16.3	8.8	7	10.9
L_{peak} (10^{35})	**0.14**	**0.8**	**1.3**	**1.1**

More details can be found in Vitaly's talk in RF7

Highlighted physics at STCF/SCTF



- **Huge samples of XYZ, J/ψ, D^+, D_s^+, Λ_c^+, nucleon, hyperon:**
  - Hadron spectroscopy and QCD: exotic hadron properties, nucleon structure …
  - Flavor and CP violation: Precise independent measurements of Cabibbo angle, CP violation in hyperon and tau sectors
  - New physics: LFV, LNV, FCNC down to level of SM expectations

Summary

- BESIII has operated for over 10 years and will continue commission for another 5-10 years;
- BESIII has significant achievement in hadron physics, weak decays of charm hadrons, strong phases and CPV in hyperons;
- Next generation of tau-charm factories are proposed in China and Russia, with designed luminosity 100 times larger than BEPCII, energy region about 2-7 GeV.

Related talks in parallel session

Session	Time	Title	Speaker
RF1	15:12	Physics potential of a high-luminosity J/ψ factory	Andrzej Kupsc
RF1	13:30	Charm weak decays at BESIII and STCF	Xiaorui Lv
RF5	15:28	cLFV in tau decays	Swagato Banerjee
RF7	13:02	Physics Potential of a Super Tau-Charm Facility	Haiping Peng
RF7	13:14	Precision Experiments at Super Charm-Tau Facility	Vitaly Vorobiev
RF7	14:36	Physics in the Tau-Charm Region at BESIII	Ryan Mitchell

Thanks!

谢谢！